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Proposal for 7.75 – 8.35 kMcps Diplexer Using Side-Wall Couplers and Cut-Off Guide

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

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ABSTRACT

A diplexer may be made using two side-wall couplers interconnected by cut-off guides. Isolation is controlled by the length of the interconnecting lines. A sample design is worked out for 7.75 — 8.35 kMcps in full- and half-height WR-112 guide.

Accepted for the Air Force
Franklin C. Hudson, Deputy Chief
Air Force Lincoln Laboratory Office

PROPOSAL FOR 7.75 – 8.35 kMcps DIPLEXER USING
SIDE-WALL COUPLERS AND CUT-OFF GUIDE

The scattering matrix, S, for an ideal side-wall coupler is given by:

$$S = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 0 & 1 & j \\ 0 & 0 & j & 1 \\ 1 & j & 0 & 0 \\ j & 1 & 0 & 0 \end{bmatrix} \qquad (1)$$

The terminal or port numbering convention for the coupler is shown in Fig. 1.

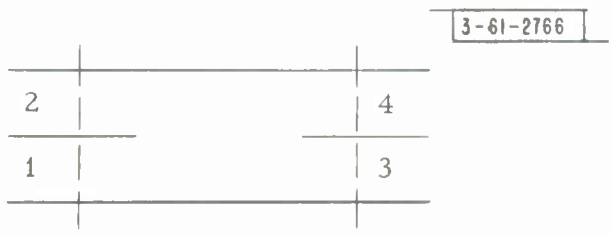

Fig. 1. Side-wall coupler port numbering convention.

Assume that a signal a_1 is incident on port 1; ports 3 and 4 are terminated in identical, lossless reflection factors $\Gamma_3 = \Gamma_4 = e^{j\theta} = \frac{a_3}{b_3} = \frac{a_4}{b_4}$. The reflected amplitude at port 1, $b_1 = \frac{1}{2} e^{j\theta} (a_1 - a_1) = 0$, and $b_2 = j\, e^{j\theta}\, a_1$. All the power incident on port 1 emerges out of port 2, if $\Gamma_2 = 0$.

But a lossless reflection factor, $|\Gamma| = 1$, is realized by a "long" section of guide below cut-off. So, if a signal of frequency f_1 is applied at port 1, and ports 3 and 4 are terminated in symmetrical sections of guide whose cut-off frequency, $f_c = f_{c3} = f_{c4}$, is above f_1, all the power comes out of port 2.

Suppose now that a_1 is an incident signal (port 1) at a frequency $f_2 > f_c$.

If at f_2 the transitions from guides 3 and 4 to the guide with cut-off f_c are matched,

$$b_3' = \frac{a_1}{\sqrt{2}} \text{ and } b_4' = \frac{ja_1}{\sqrt{2}}, \tag{2}$$

so that the emergent signals at ports 3' and 4' (in small guide) are of equal amplitude and phase quadrature.

If b_3' and b_4' are in turn fed into a second hybrid, similar to Fig. 1, then for ports 3 and 4 of the second hybrid,

$$b_3 = 0 \text{ and } b_4 = ja_1. \tag{3}$$

Figure 2 is a schematic of the above arrangement.

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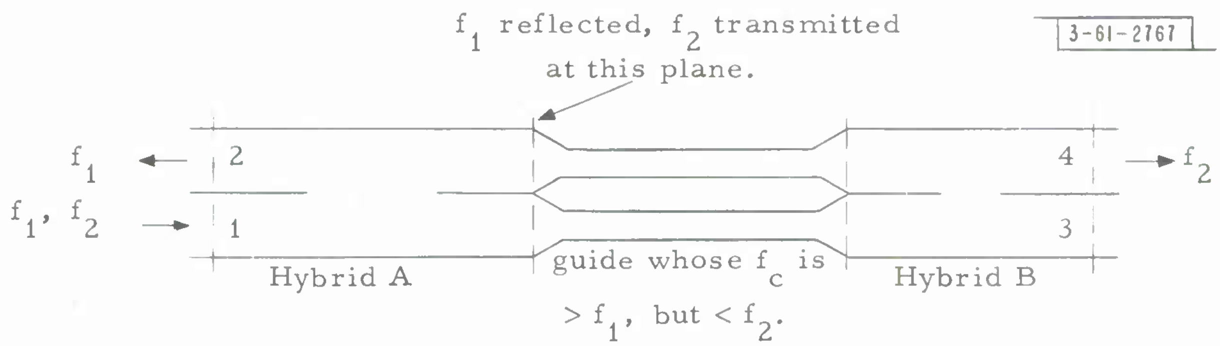

Fig. 2. Schematic of proposed diplexer using two side-wall hybrids and below cut-off guide interconnecting lines.

In Fig. 2 the transition from hybrid to interconnecting lines is indicated as a taper[1] of some sort. For a wide band at f_2 this might be necessary; however, for $\pm$ tens Mc band at f_2 it should be possible to use an abrupt junction (which is inductive[2]) but tuned out with a capacitive screw, followed by a quarter-wave transformer.

Anticipated Attenuation Values for Rectangular Guide — It is assumed that the hybrids are in WR-112 guide; f_1 = 7.75 kMcps, f_2 = 8.35 kMcps. f_c of interconnecting lines must be between f_1 and f_2.

The isolation between port 2 and port 4 (Fig. 2) at f_1 would be dependent upon the attenuation of interconnecting lines when the lines are below cut-off, i.e., $f_1 < f_c$. The relation is[3]:

$$\alpha = \frac{2\pi}{\lambda_c} \sqrt{1 - \left(\frac{f}{f_c}\right)^2} \quad \frac{\text{nepers}}{\text{unit length of } \lambda_c} \tag{4}$$

Figure 3 is a plot of Eq. (4) with f_c varying between 7.83 and 8.33 kMcps. An isolation of 3 to 5 db/cm may be realized, depending on choice of f_c. 60 db of isolation would be given by approximately 15 cm length of guide.

At f_2, between ports 1 and 4, there will be dissipative loss due to conductor loss. For $f_2 > f_c$ the relation is[4]:

$$\alpha_c = \frac{R_s}{b\eta_1 \sqrt{1 - \left(\frac{f_c}{f}\right)^2}} \left[1 + \frac{2b}{a} \left(\frac{f_c}{f}\right)^2\right] \frac{\text{nepers}}{\text{unit length of b}}, \tag{5}$$

where a, b = dimensions of guide,

η_1 = 377 ohms for air dielectric,

R_s = $2.61 \times 10^{-7} \sqrt{f}$ ohms/square for Cu.

For WR-112 guide ($a = 1.122''$, $b = .497''$) and $f = 7.05$ kMcps, Eq. (5) gives 0.0273 db/ft. for C_u and 0.0525 db/ft. for Brass, using $\frac{R_s \text{ Brass}}{R_s C_u} = 1.92$. This disagrees with Microwave Engineers' Handbook[5] which quotes 0.0412 db/ft. for Brass. Since Eq. (5) gives pessimistic values, no correction will be made. Figure 4 is a plot of Eq. (5) for $f = 8.35$ kMcps and f_c varying from 8.0 to 8.3 kMcps, for Cu WR-112 guide as well as for half-height WR-112 guide. For $f_c = 8.05$ kMcps the anticipated loss is 0.11 db/ft. for full height guide and 0.16 db/ft. for half-height guide.

From Fig. 3, at $f_c = 8.05$ kMcps, 60 db isolation requires about 6 inches, so that for two hybrids and 6-inch interconnecting lines no more than 1/2 db insertion loss should be anticipated at f_2.

If an abrupt 180° E-plane bend[6] is used, the over-all length might be about 8 to 9 inches.

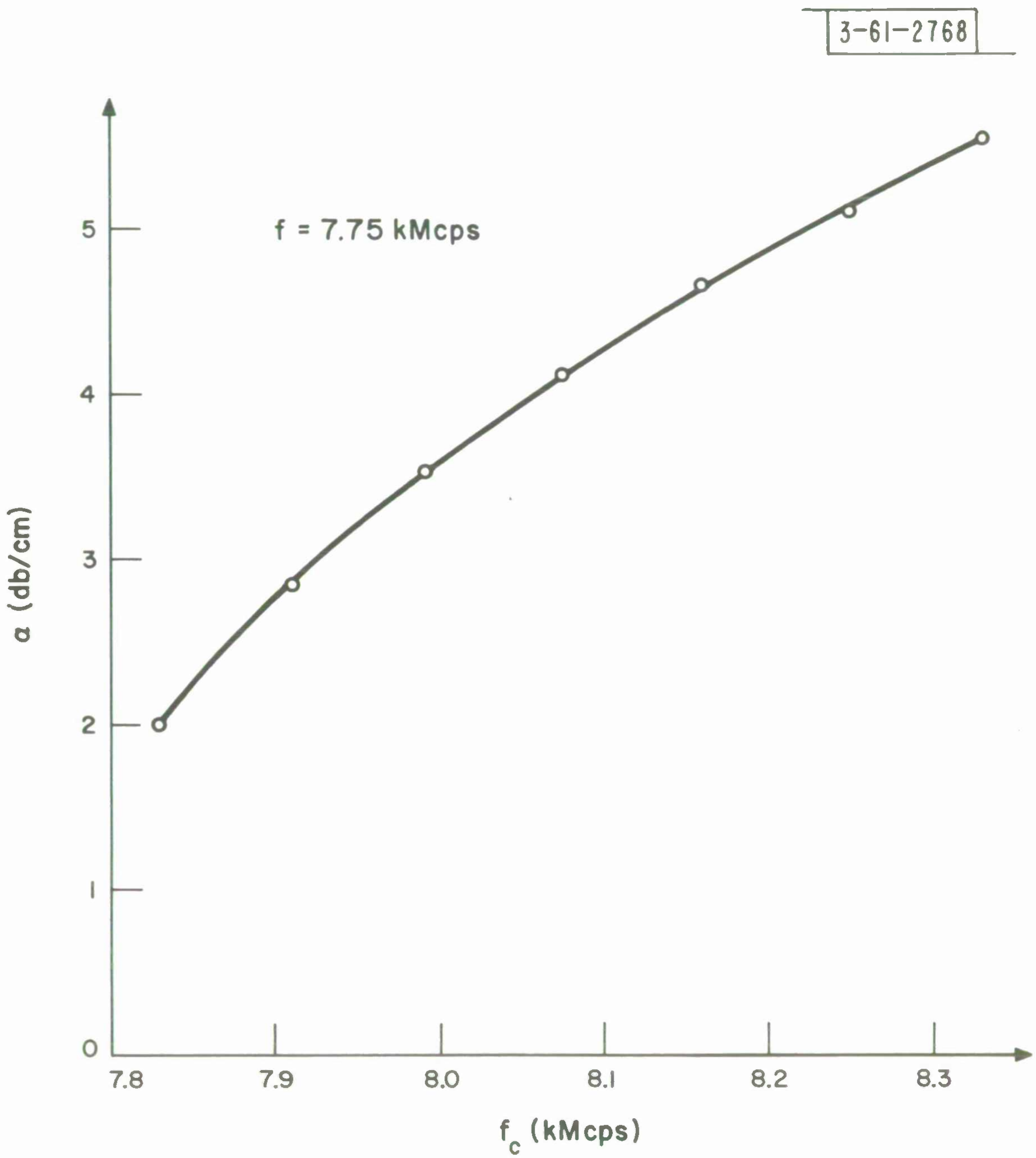

Fig. 3. Computed attenuation for rectangular guide below cut-off — ideal guide.

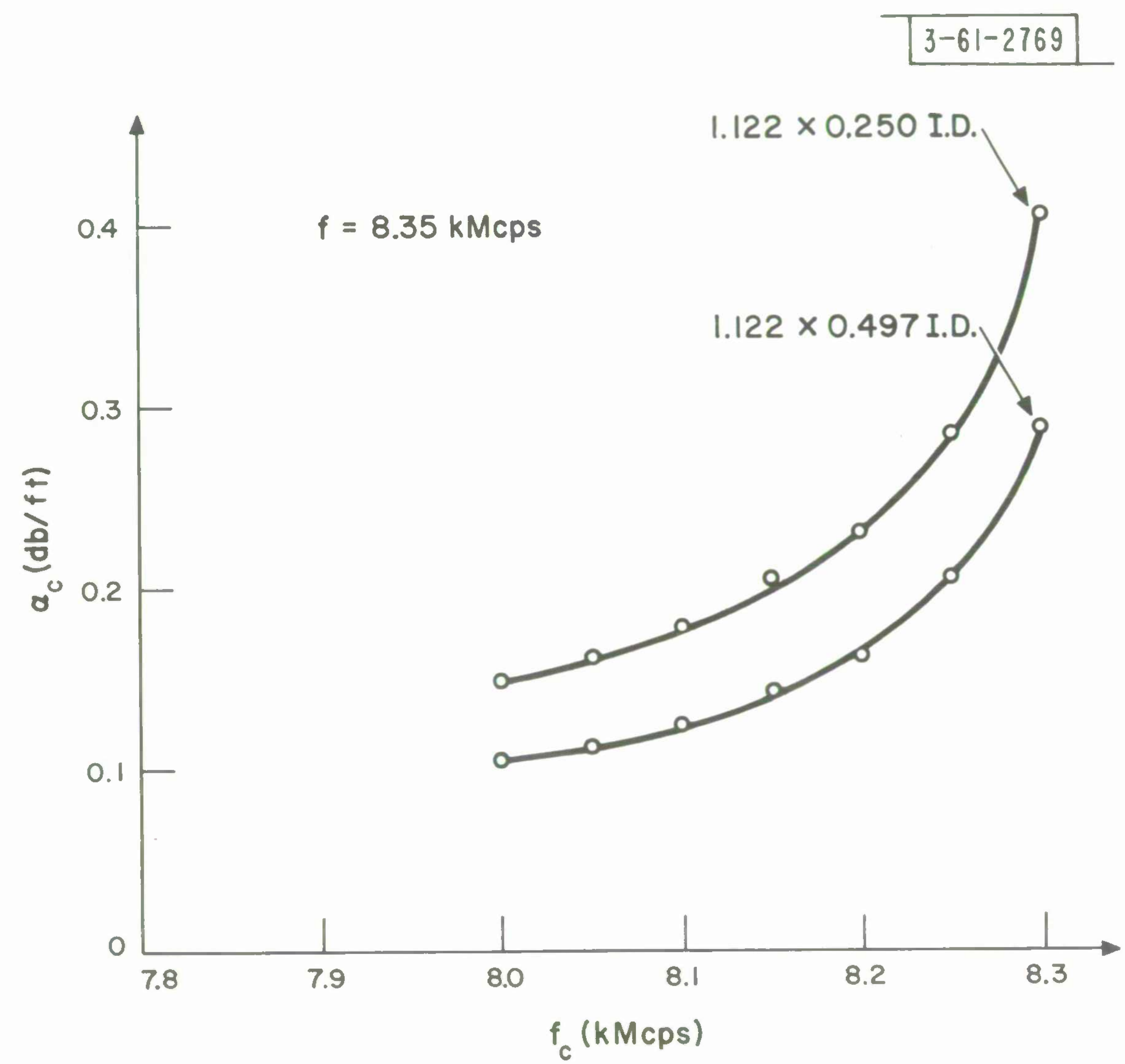

Fig. 4. Computed attenuation due to conductor loss for rectangular copper guide – above cut-off.

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